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USE AND EFFECTIVENESS OF SHOULDER HARNESS IN SURPLUS MILITARY AIRCRAFT FLOWN BY CIVILIAN PILOTS

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Cornell University Medical College
A Study Sponsored by the Departments of Navy and Air Force

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USE AND EFFECTIVENESS OF SHOULDER HARNESS IN SURPLUS MILITARY AIRCRAFT FLOWN BY CIVILIAN PILOTS

Hugh De Haven
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A Study Sponsored by the Departments of Navy and Air Force
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FOREWORD

This report was prepared by the Crash Injury Research project under ONR Contract No. N6onr-264-12. The project, initiated in 1942, is jointly supported by the Departments of the Navy and the Air Force and is identified as ONR Project NR 118-782 (Navy) and RDO No. R695-65 (Air Force). The work is under the direction of Hugh DeHaven, Research Associate in the Department of Public Health and Preventive Medicine of Cornell University Medical College. The project is advised by a joint Navy - Air Force Technical Group. The technical director of the project for the Department of the Navy is Dr. F. H. Quimby of the Office of Naval Research, and the technical director of the project for the Department of the Air Force is Dr. H. E. Savely of the Aero Medical Laboratory, Research Division, Wright Air Development Center.

Crash Injury Research is particularly indebted to state and federal aircraft accident investigating groups upon whose reports this study is based, and to Dr. John D. Coakley of Dunlap and Associates, Inc., New York, N. Y., who assisted in the preparation of the statistical analysis presented herein.

ABSTRACT

Eighty-two accidents involving surplus, single-engine military trainer aircraft flown by civilian pilots are studied to ascertain the use and effectiveness of shoulder harness.

The data suggest that a large proportion of civilian pilots do not realize the value of shoulder harness. Only a small percentage of civilian pilots studied retained harness in their aircraft. However a majority of the group, when accidents occurred, were wearing shoulder harness.

Statistical analysis shows that shoulder harness does effectively decrease the probability of dangerous head injury so long as the cockpit or cabin structures remain substantially intact in severe accidents.

PUBLICATION APPROVED

Manuscript Copy of this report has been reviewed and found satisfactory for publication.

For the Commanding General:

Robert H Blount Col USAF (MC)

for Walter A. Carlson
Colonel, USAF (MC)
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For the Office of Naval Research:

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INTRODUCTION

The development of several new types of shoulder harness now being considered for military personnel and civilian pilots has aroused discussion as to (1) how many pilots understand the value of shoulder harness, and (2) whether civilian pilots will routinely use harness if it is provided as standard equipment.

Aircraft manufacturers have claimed that civilian pilots do not want harness in their planes and would not use harness if it were provided as standard equipment. These arguments have been supported by the fact that civilians rarely install shoulder harness or chest straps in their aircraft. It has also been claimed that many private pilots actually have removed shoulder harness from aircraft in which harness was installed as original equipment.

Although the effectiveness of shoulder harness in military fighter and trainer aircraft has been studied, there appears to have been no formal report giving data on the percentage of cases in which civilian pilots leave shoulder harness in surplus military aircraft - and use it.

In order to study these problems, accident-injury details on 82 crashes of surplus, single-engine military trainers formerly used by the Navy and Air Force were drawn from CIR files. The types of aircraft selected were: Vultee BT-13 and 15, Fairchild PT-19 and 26, and Stearman PT-17. These planes were reported to have been equipped with shoulder harness as a standard military installation.

Approximately 5,000 of these aircraft are now in use by civilian pilots; the sample of 82 cases therefore represents slightly more than 1-1/2% of the total number of these aircraft. CAA data on personal plane accidents for the year 1949 indicate that about 1 out of every 60 planes was involved in a serious or fatal accident of the type studied for this report. Presumably, if this rate holds for the type of aircraft studied herein, - and no data have been found which would indicate otherwise - this group of 82 accidents is about numerically equivalent to the severe accidents in which such surplus military trainers are involved annually. However, these 82 accidents have been collected over a period of several years and, therefore, they are a sample of survivable accidents and not a complete listing of all the accidents in which the aircraft listed above have been involved.

USE OF SHOULDER HARNESS

Proportion of Aircraft from which Shoulder Harness had been Removed

All data pertinent to each accident, such as CAB and State accident reports, accident-injury forms and medical reports were carefully examined to determine how many of the aircraft were equipped with shoulder harness at the time of the accident. As an additional check, photographs of the aircraft wreckage and of the cockpits were studied in each case under a high-power lens.

Tabulation of the results shows that shoulder harness installations were present in only 26 of the aircraft, and that the harness had been removed from 56, or 68% of the 82 aircraft. A bar-graph depicting the ratio of aircraft with harness as against aircraft without harness is shown in Figure 1. Evidently the harness had been removed from about 2 out of every 3 aircraft.

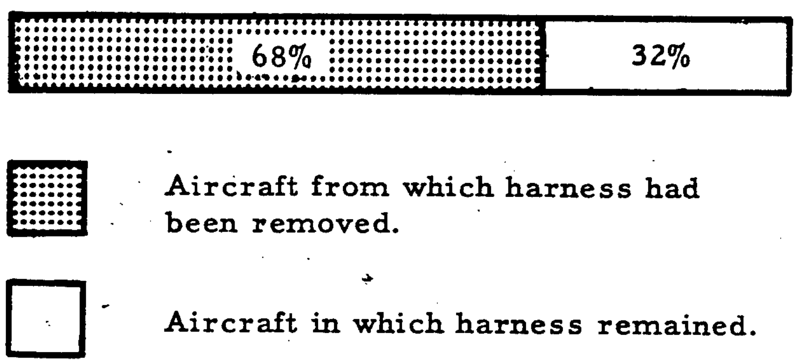

Fig. I. The percentage of aircraft, of 82 surplus, single-engine military trainers studied by CIR, from which original shoulder harness installations had been removed, and the percentage in which harness remained.

Removal of shoulder harness installations from an aircraft requires definite action; the evident expenditure of time and labor in its removal suggests either: (1) insufficient understanding of its value, (2) willingness to take chances, (3) discomfort or inconvenience of wearing harness, or (4) to keep it from "flopping around" in the cockpit when not in use.

A conservative estimate of the total number of these surplus air-

craft now in use by civilian pilots is 5,000 aircraft. So far as can be determined, this sample of 82 cases is representative in regard to removal and retention of harness. If the ratio shown in Figure 1 holds for all of these single-engine military trainers, the shoulder harness has been removed from approximately 3,500 of these aircraft.

Proportion of Pilots who Wear Harness when it is Retained in Aircraft

The 82 accident cases were further analyzed to find what proportion of civilian pilots wear shoulder harness when they keep it in their aircraft. In 19 out of 26, or 73% of the cases, the pilots used the harness when it was retained in the airplane.

Figure 2 shows how the 32% of cases in which the harness was retained is subdivided into cases in which the harness was and was not used.

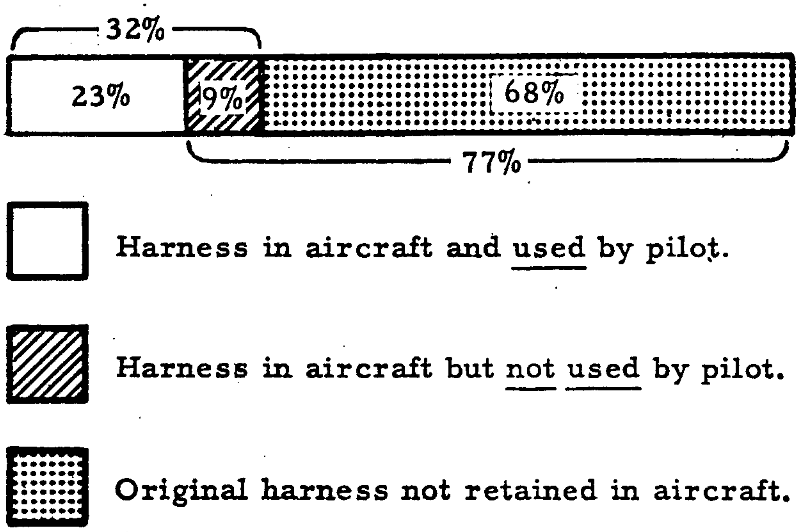

Fig. 2. Percentage comparison of use, non-use, and removal of harness in 82 surplus military aircraft.

The percentages shown in Figure 2 indicate that harness was kept in 1 of every 3 of these surplus aircraft, and that harness was being used in only 1 out of 4 accidents. If these ratios are applied to the 5,000 surplus aircraft in use by civilian pilots, it may be estimated that about 1,500 of these aircraft still have shoulder harness and that harness is being utilized in about 1,300 of them.

EFFECTIVENESS OF SHOULDER HARNESS IN ACCIDENTS

To determine the effectiveness of shoulder harness, each of the 82 accident cases was classified according to the severity of crash conditions. The six classes of accident severity used by CIR are: minor, moderate, major, severe, extremely severe, and extreme.

Many facts about each accident were taken into account before assigning it to one of the six classes. Among the items considered were: flight path angle of the aircraft, attitude at impact, impact speed and stopping distance (deceleration) with respect to the type of terrain or objects struck by the aircraft. Other factors considered were: amount of demolition or displacement of nose sections, wings, landing gear and cabin or cockpit structure, as well as the condition of the seats, safety belts, shoulder harness, and of the cockpit structure near the pilot.

Although other observers might occasionally differ in their placement of borderline cases in one group or another, there is no reasonable question but that the groups represent a progressive increase in accident severity.

In classifying the 82 cases it was found that none fell into the "minor" classification in which crash force, damage to the aircraft and exposure to injury are all so trivial as to preclude any positive testing of the protective value of harness. In judging the effectiveness of shoulder harness, it should be borne in mind that the purpose of harness is to protect the upper parts of the body - particularly the head - by preventing these vulnerable areas from striking objects inside the cabin or cockpit under survivable conditions of crash force. Obviously, harness cannot normally afford protection in "extreme" accidents in which cockpit or cabin structures are demolished. The criteria for the classification of accidents in the extreme category require that crash force and demolition of aircraft structure in the vicinity of the cockpit or cabin be so great that inevitably there will be extreme and multiple crushing injuries to many or all parts of the body. Accordingly, 13 extreme accidents which served in the study of "harness use" were found to have no value in estimating "harness effectiveness" for they represented extreme cases in which the protective value of harness installations could not be observed and was presumably zero. These 13 extreme accidents were therefore eliminated from the study of harness effectiveness, leaving 69 cases, none of which were minor or extreme. These 69 cases ranged in severity from moderate to extremely severe. This group of cases can be described as serious but survivable accidents.

Typical examples of the different classes of accident severity are shown in Figures 3, 4, 5, and 6.

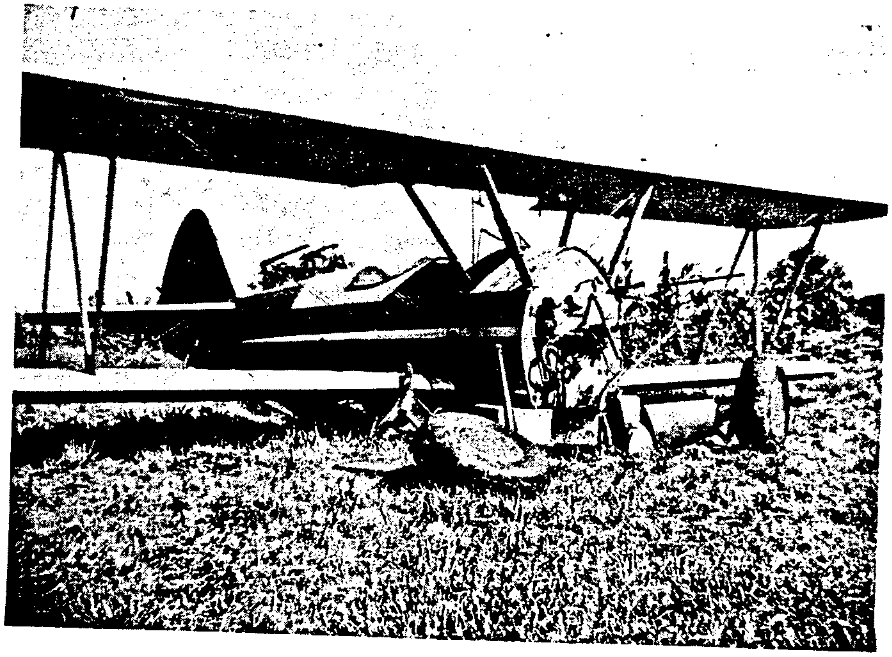

Fig. 3. Moderate accident. Shoulder harness was available but was not used. Pilot sustained a broken neck with paralysis.

Fig. 4. Major accident. Shoulder harness available but not used. Pilot sustained non-dangerous head injuries.

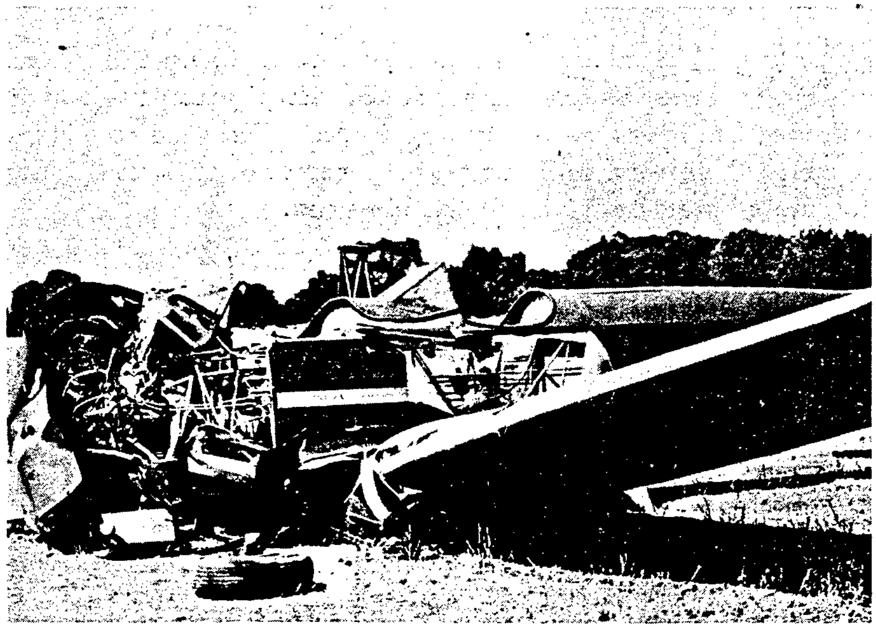

Fig. 5. Severe accident. No shoulder harness available. Pilot (in rear seat) sustained dangerous head injuries which resulted in death.

Fig. 6. Extremely severe accident (note telescoping of rugged cockpit structure). Shoulder harness was available and used by pilot who sustained non-dangerous head injuries.

A further simplification results from combining the severe and the extremely severe classes into one group. In the analysis which follows, three classes of accident severity are used. They are: (1) moderate, (2) major, and (3) severe and extremely severe. Figure 7 shows a distribution of the 69 accidents in these classes.

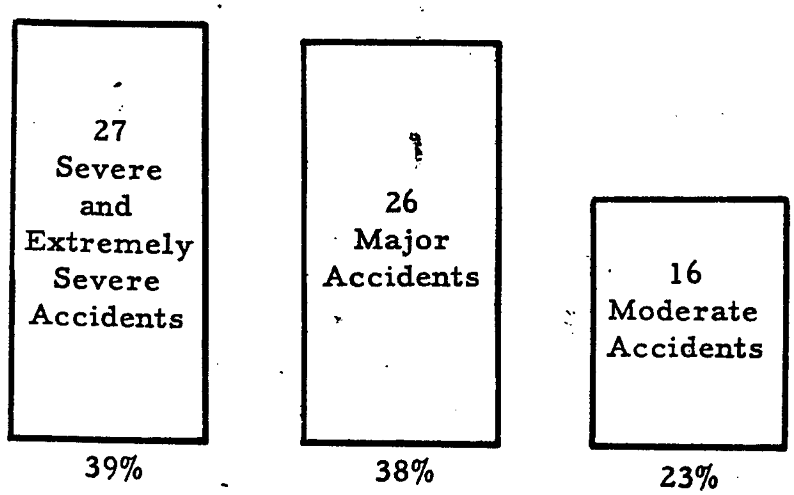

Fig. 7. Distribution of 69 survivable accidents into three classes differing in crash force, direction of force, and structural damage.

In studying the effectiveness of shoulder harness in reducing the probability of dangerous head injury it was necessary to divide the head injuries sustained by the pilots into groups representing differences in seriousness of injury. By dividing the accidents into groups differing in severity, and injuries into groups differing in seriousness, the interrelationships among the following three variables could be studied: (a) severity of accident, (b) seriousness of injury, and (c) use of harness.

Specific criteria and definitions used for evaluating head injuries had been developed by CIR with the assistance of members of the staff at New York Hospital and Cornell University Medical College. These criteria were employed in allocating the seriousness of head injury to groups designated as: (1) dangerous, (2) non-dangerous, (3) minor, and (4) no head injury.

Dangerous head injuries include: A period of unconsciousness exceeding 30 minutes, skull fracture, severe concussion or other evidence of dangerous intra-cranial injury, etc.

Non-dangerous head injuries include: Severe contusions and/or lacerations, fractured facial bones, moderate concussion, a period of unconsciousness not exceeding 30 minutes without other evidence of intra-cranial injury.

Minor head injuries include: Contusions and/or lacerations and abrasions, fractures of the nose, state of being dazed or slightly stunned, mild concussion, mild headache without loss of consciousness.

Figure 8 shows the distribution of the seriousness of the injuries of the head in the 69 survivable accidents.

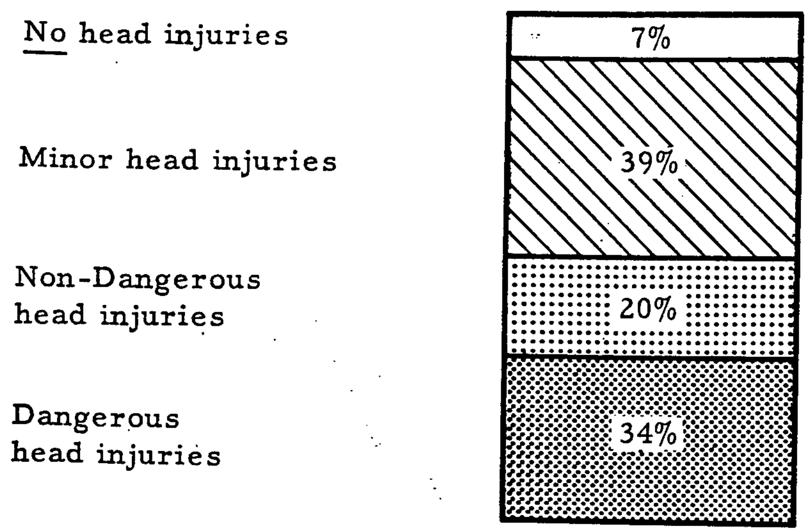

Fig. 8. Distribution of seriousness of head injuries in 69 accidents involving surplus military trainers flown by civilian pilots.

For purposes of analysis the data were also separated according to the "harness-use" variable. The three conditions are:

(1) Cases in which shoulder harness was <u>used</u> and <u>effective</u>;

(2) Cases in which shoulder harness was <u>used</u>, but was <u>ineffective</u>*;

(3) Cases in which shoulder harness was <u>not used</u>.

---

* Ineffective harness includes cases in which the harness was not locked, or some portion of the harness installation (anchorages, attachment structure, webbing, etc.) failed.

Table I is a tabulation of the head injuries in the 69 survivable accidents according to the three variables which have just been described.

TABLE I

Severity of accidents, seriousness of head injury, and use of shoulder harness in 69 accidents involving surplus military trainers.

Extremely Severe and Severe Accidents	Harness Used and Effective	Harness Used but Ineffective	Harness Not Used
Dangerous Head Injury	0	0	15
Non-dangerous Head Injury	0	1	3
Minor Head Injury	4	0	4
No Head Injury	0	0	0
Total 27	4	1	22

Major Accidents	Harness Used and Effective	Harness Used but Ineffective	Harness Not Used
Dangerous Head Injury	0	3	5
Non-dangerous Head Injury	1	1	6
Minor Head Injury	0	1	6
No Head Injury	3	0	0
Total 26	4	5	17

Moderate Accidents	Harness Used and Effective	Harness Used but Ineffective	Harness Not Used
Dangerous Head Injury	0	0	0
Non-dangerous Head Injury	0	0	2
Minor Head Injury	1	1	10
No Head Injury	1	0	1
Total 16	2	1	13

In the upper section of Table I there are twenty-seven instances of severe and extremely severe accidents. Among these accidents it will be observed that there were no cases of dangerous head injury when harness was used. However, there were 15 cases of dangerous head injury when harness was not used. Furthermore, there was only one non-dangerous head injury when harness was used as compared with three cases when the harness was not used. In the column labelled "harness used and ineffective", there was one case in which the harness installation was broken as a result of the crash.

Examination of the data in Table I suggests:

(1) That the danger of head injury is related to the use of harness;

(2) That there is a lack of serious head injury when harness is worn and is effective; and

(3) That injuries of the head often occur when harness is not used, or is ineffective.

This array of data can be arranged in a variety of ways to test the correlation between these variables. One interesting way is to arrange the data as shown in Table II.

TABLE II

Seriousness of head injury in relation to effectiveness and use or non-use of shoulder harness.

Head Injury	Harness Used and Effective	Harness Used but Ineffective	Harness Not Used	Total
Dangerous	0	3	20	23
Non-Dangerous	1	2	11	14
Minor	5	2	20	27
No Injury	4	0	1	5
	10	7	52	69

A chi-square test of this array yields a P-value which is less than .01. Consequently, such an array would not be expected to arise by chance sampling of a population in which the two variables were unrelated. This significant relationship is interpreted to mean that the use of harness helps to prevent or to lessen the seriousness of head injuries sustained by persons involved in survivable crashes in airplanes of the types under discussion. The severity of crashes, it will be recalled, excludes accidents where plane damage is trivial, on the one hand, and extreme (disintegration type accidents) on the other. All degrees of accident severity between these extremes are included.

Systematic rearrangement and testing of the data in Table I reveals several facts and trends which are of interest:

1. The protective value of harness seems to increase as the severity of the accident increases. One inference from this trend is that harness will be valuable in protecting the pilot's head up to a point where crushing injuries are sustained due to collapse of surrounding structures.

2. In less severe accidents one function of the harness appears to be to prevent even minor injuries to the head.

3. Most combinations of the data yield chi-squares which are significant at the 1% level of confidence. Several combinations yield chi-squares which far exceed the requirements for the 1% level of confidence. The data can be combined into a 2 x 2 table so that there will be a larger number of cases in each cell. Chi-squares significant at the 1% level of confidence are still obtained.

4. The question of harness which is <u>ineffective</u> can be further examined. When data from the "harness used but ineffective" column are combined with the "harness used and effective" data and this combination is compared with "harness not used" data, the relation between harness use and severity of injury tends to disappear. One might defend this combination of data by arguing that irrespective of whether or not the harness installation failed, it <u>was used</u> and some protection was provided. The disappearance of a significant relationship suggests that, even though some protection might have been provided by the harness before it failed, the degree of protection was very different from that provided by harness installations which did not fail and were fully effective.

On the other hand, if one argues that cases in which the harness is ineffective are similar to those in which no harness was used and then combines these data for comparison with the data for "harness used and effective", it will be found that the correlation between harness use and avoidance of injury is higher than when the data are kept separate. These facts suggest that shoulder harness installations which break or are ineffective in accidents afford only slightly better protection, if any, than having no harness at all. One inference which suggests itself is that unlocked harness is ineffective and that the heavy jolt loads applied to unlocked harness may snap it without materially reducing the velocity and momentum of the upper parts of the body and the head. Full and effective protection is provided only when the harness installation is locked and is strong enough to withstand the forces applied to it at the time of the accident.

When evaluating the findings of this report, it should be noted that the shoulder harness installations used in these planes were not equipped with automatic inertia locks; the shoulder harness had to be locked manually in an emergency. The danger of this condition was augmented by an arrangement of instruments and controls, some of which were beyond reach of the pilot when the harness was locked. These factors, plus inadequate strength in anchorage points, unquestionably reduced both the use and the effectiveness of these early World War II installations.

DISCUSSION

The results of this study show that a large majority of civilian pilots remove military-type shoulder harness installations from surplus military aircraft. Although the reasons for removal have not been systematically determined, pilots have mentioned the following objections to the harness installations used in World War II trainers: (1) the inconvenience of putting the harness on and taking it off; (2) the discomfort encountered when wearing the harness; (3) binding of the shoulders which, in turn, makes it difficult for the pilot to reach certain cockpit controls unless he unlocks the harness; and (4) the necessity of adjusting the harness webbing to fit persons differing in size.

The following attitudes and opinions have been observed among pilots: (1) some do not realize that harness reduces the probability of dangerous head injury in severe accidents; (2) some believe that the use of harness causes broken necks; and (3) some are willing to "take a chance" that they will not be involved in a crash.

The facts developed in this study and in other reports clearly indicate that, if pilots would wear properly designed harness, especially when danger is imminent, accident casualties would be reduced. This means, presumably, that more pilots would emerge from accidents without injuries, the injuries sustained would be less serious, and there should be more crash survivors.

The problem of getting civilian pilots to wear shoulder harness appears to consist of two parts:

1. Indoctrination concerning the value of harness, and

2. Development of a comfortable and convenient restraining device which will effectively check the forward momentum of the head and chest as well as the hips, and which:

    (a) Will not be inconvenient to put on or take off, and

    (b) Will overcome present claims of discomfort in use.

CONCLUSIONS

Analysis of 82 accidents involving surplus, single-engine World War II military trainers which were originally equipped with shoulder harness shows that:

1. There was no evidence of shoulder harness in 68% of the planes.

2. The harness had evidently been removed or was not used at the time of the accident in 77% of the cases.

3. However, 73% of the pilots who retained harness in their aircraft were wearing harness at the time of their accidents.

4. When shoulder harness is not worn the probability of head injury in survivable accidents is significantly greater than when harness is worn. In this sample, when shoulder harness was not worn, non-dangerous head injuries occurred twice as frequently and dangerous and non-dangerous injuries, taken together, occurred 6 times as frequently.

5. A significant improvement of safety in civilian flying can be achieved in survivable accidents by: (a) indoctrinating pilots in the protective value of shoulder harness, and (b) providing a type of shoulder harness which will be more acceptable to civilian pilots.